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BUBBLE COLLAPSE ADJACENT TO A RIGID WALL, A FLEXIBLE WALL, AND A SECOND BUBBLE

by

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I. INTRODUCTION

The effect of a nearby object on the collapse of an initially spherical bubble is of great interest in the study of bubble behavior in cavitation, boiling, and related fields. Recent studies, both theoretical and experimental[1, 2, 3, 4 e.g.], are beginning to shed light on this area; however, much remains to be done. This paper presents some preliminary results of a photographic nature from thesis work[5] of the first author, presently underway. These results consist of high speed motion picture sequences taken of single bubbles collapsing close to 1) a rigid boundary, 2) a flexible boundary and 3) a second bubble. All are in a beaker containing room temperature tap water.

II. EXPERIMENTAL SETUP

Single bubbles were generated in an open water beaker (box) by discharging a capacitor charged to 10 KV across a gap between two electrodes. For the case of two bubbles collapsing adjacent to each other two such electrode pairs were connected in series. The box cross-section was 6" x 6" and the submergence head above the bubbles was approximately 3". The bubbles were lighted with diffuse backlight and photographed with a Beckman and Whitley Dynafax Camera at 2.5×10^4 frames/second. Exposure times of 1μs were used. The final picture in Fig. 1 shows the scale of the photographs (1 division = 1 mm). Beneath each picture in Figs. 1, 2, and 3 is given the time in microseconds from the spark discharge.

III. RESULTS AND CONCLUSIONS

The case of an initially spherical bubble collapsing next to a rigid surface has been theoretically modeled by Mitchell[1] of this laboratory and Chapman.[2] In general these studies show that as the collapse progresses the bubble first elongates into an ovoid with its long axis perpendicular to the surface, then migrates towards the surface, and then the side furthest from the wall collapses forming a liquid jet which penetrates the wall nearest the surface, finally striking the surface. Fig. 1, selected frames from our photographic sequence showing a bubble collapsing next to a brass plate, and Fig. 4, a plot of the wall position of this bubble as a function of time, graphically show the qualitative validity of these models. This results is also in agreement with the observations of Kling[3] from this laboratory, and Gibson.[4]

It is apparent that the case of two bubbles collapsing adjacent to each other is equivalent to that of one bubble collapsing next to an infinitely rigid wall placed at the plane of symmetry between the two bubbles. Fig. 2, selected frames from our photographic sequence showing two bubbles collapsing in proximity to one another and Fig. 5, a plot of the wall position of these bubbles as a function of time, confirms the above expectations.

Another case of interest in bubble mechanics is the case of a single bubble collapsing adjacent to a flexible surface. Fig. 3 consists of selected frames from our photographic sequence showing a bubble collapsing adjacent to a rubber membrane backed by air and Fig. 6 is a plot of the wall position of these bubbles as a function of time. These figures show that in this case the bubble is repelled from the surface and forms a jet which is oriented away from the surface. It is interesting to note that the membrane bulges outward to facilitate the flow toward the bubble for this process. This observation is in agreement with Gibson's work.[4]

Additionally Figures 4, 5, and 6 show that a solid wall slows the collapse comparing with the Rayleigh collapse time, while a flexible wall accelerates it. The second bubble seems not to affect collapse time in this experiment.

Finally, it was observed that a single bubble away from the wall, perturbed by the asymmetric gravity field, maintained approximate symmetry down to a radius ratio $O.1$ and well into the rebound.

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4. D. C. Gibson, "The Collapse of Vapour Cavities", Ph. D. Thesis, Cambridge University (1967).
5. E. E. Timm, Ph. D. Thesis, Chem. and Met. Engr. Dept., Univ. of Michigan, Ann Arbor, Michigan, in progress.

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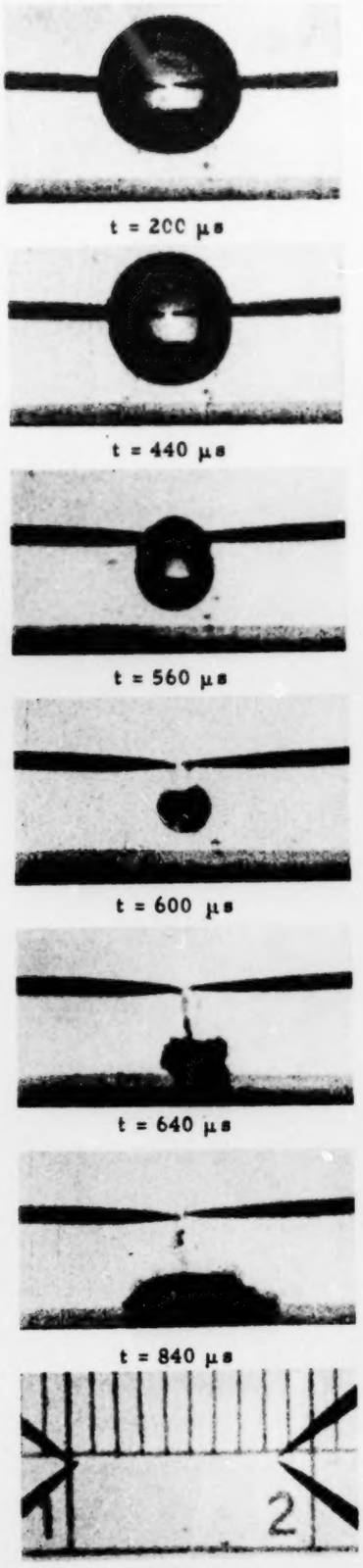
**Professor-in-Charge



Scale

Figure 1. Bubble Collapse Adjacent to a Brass Plate

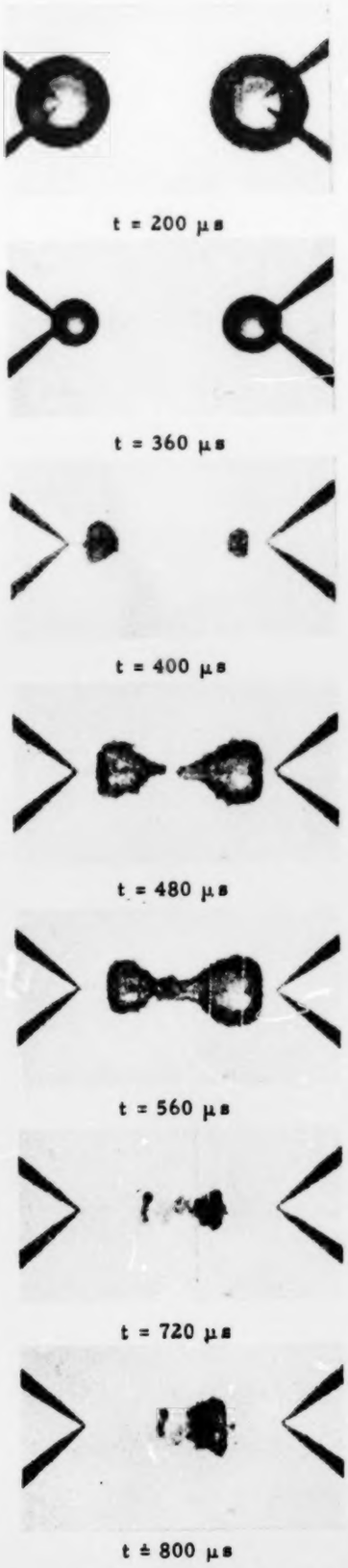


Figure 2. Bubble Collapse Adjacent to Another Bubble

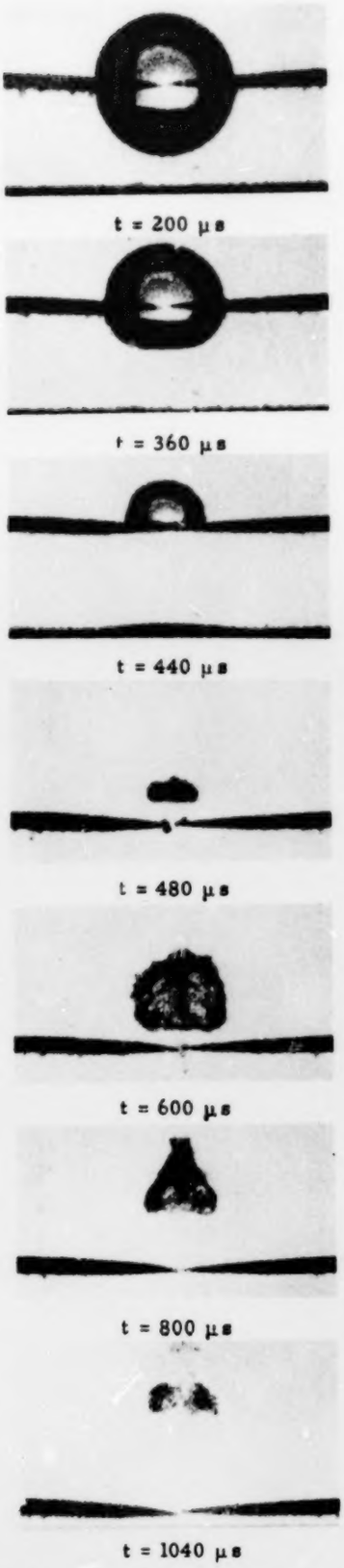


Figure 3. Bubble Collapse Adjacent to a Rubber Membrane

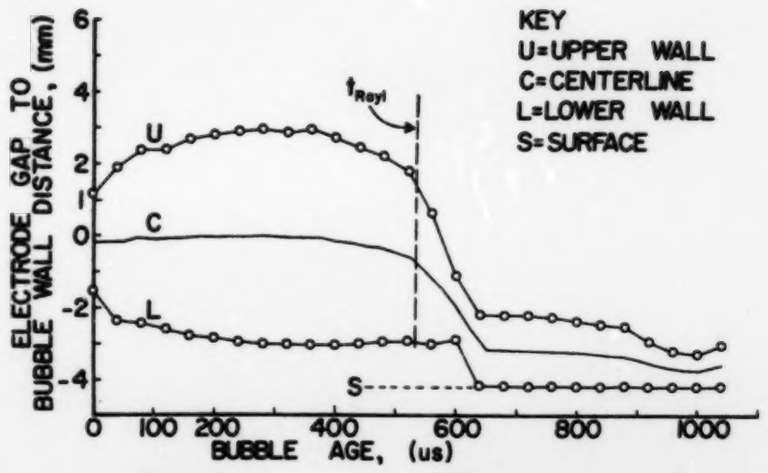


Figure 4. Apparent Wall Position Along the Axis of Symmetry as a Function of Time for a Bubble Collapsing next to a Brass Plate

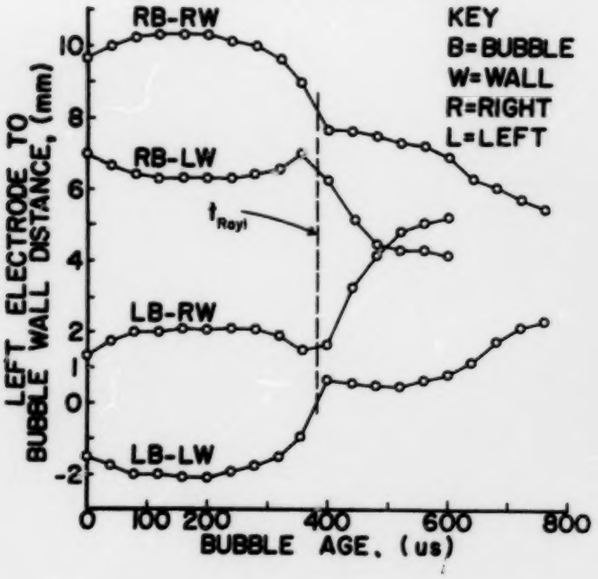


Figure 5. Apparent Wall Position Along the Axis of Symmetry as a Function of Time for a Bubble Collapsing Adjacent to Another Bubble

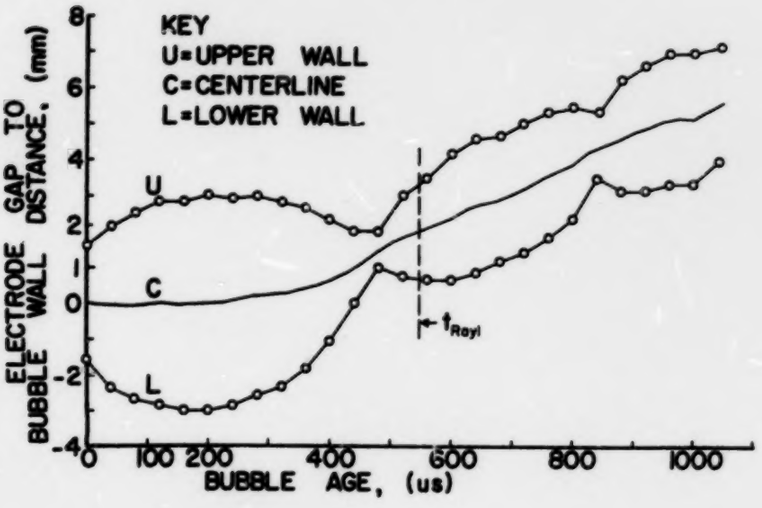


Figure 6. Apparent Wall Position Along the Axis of Symmetry as a Function of Time for a Bubble Collapsing Adjacent to a Rubber Membrane.